PHYTOTOXICOLOGY SURVEY REPORT:

UCAR CARBON CANADA INCORPORATED

WELLAND, 1992 AND 1993

JULY 1994

Ontario

Ministry of
Environment
and Energy

ISBN 0-7778-2930-7

PHYTOTOXICOLOGY SURVEY REPORT:

UCAR CARBON CANADA INCORPORATED

WELLAND

1992 AND 1993

JULY 1994

Cette publication technique
n'est disponible qu'en anglais.

PIBS 3193

PHYTOTOXICOLOGY SURVEY REPORT:

UCAR CARBON CANADA INCORPORATED

WELLAND

1992 & 1993

Report prepared by:

William I. Gizyn
Standards Development Branch
Phytotoxicology Section
Ontario Ministry of Environment and Energy

Report No: SDB-002-3512-94

Abstract

Phytotoxicology Survey Report:
UCAR Carbon Canada Incorporated
Welland - 1992 & 1993
Report No: SDB-002-3512-94

In 1992 and 1993 surveys involving collection of soil and foliage samples, with subsequent analysis for polynuclear aromatic hydrocarbons (PAH) were conducted in the vicinity of UCAR Carbon Canada Incorporated in Welland. This company manufactures carbon and graphite electrodes. The soil samples collected near the plant were clearly contaminated by PAHs emitted by UCAR. Evidence of this source-related contamination was restricted to the immediate vicinity of the plant. Tree foliage contamination indicated current, ongoing deposition.

Table of Contents

1 Introduction

Union Carbide Canada Limited operates a carbon and graphite electrode manufacturing facility in Welland. This UCAR Carbon Canada Incorporated plant is located on an 'L'-shaped property in the southern part of the city. It consists of several buildings and other structures, distributed over approximately 40 hectares. In this report, this facility will be referred to as UCAR.

The primary raw materials for the production of carbon and graphite electrodes are anthracite coal or petroleum coke and coal tar pitch. The process involves mixing the raw materials, forming or extruding the mix, and baking at high temperatures. Graphite electrodes are produced by impregnating the carbon electrodes with more pitch and baking again.

Due to the nature of the raw materials and the high temperatures involved, the production of carbon and graphite electrodes is associated with emissions to the atmosphere of a variety of organic compounds.

One group of compounds that could be emitted are polynuclear aromatic hydrocarbons, commonly known by the acronym, PAH. Chemically these compounds consist of carbon and hydrogen atoms in two or more benzene rings. The properties of individual PAH compounds are determined by the number and orientation of these rings. Coal tar pitch consists primarily of PAHs.

In April 1992, the MOEE Welland District Office requested that the Phytotoxicology Section conduct a survey that would evaluate the impact of PAH emissions by UCAR on the residential neighbourhoods near the plant.

2 Survey Design

The Phytotoxicology Section utilizes soil and vegetation as indicators of airborne contaminants. A typical survey design consists of one or more transect lines originating at the suspected source of the contaminant. At regular intervals long these lines, homogeneous receptors are located and sampled.

This approach was not amenable to the UCAR survey. The UCAR property had numerous potential sources of PAH compounds. Residential properties were located in the north through east quadrant. The other quadrants contained industrial properties and transportation corridors, or were vacant or agricultural land.

The residential neighbourhoods that were the focus of concern with respect to PAH deposition, offered the greatest potential for locating suitable homogeneous receptors. The receptors would be soil from undisturbed yards and tree foliage from a common species. A typical sampling site consisted of a rear yard of a single-family house with a lawn grass cover and a silver maple tree. The house would be at least 25 years old and discussions with the occupant would attempt to eliminate properties were new sod had recently been laid.

A total of 15 properties were selected for sampling of the two receptors. Thirteen of these were in the UCAR vicinity and two control properties were located about 3.5 kilometres to the north. All but one of the properties met the criteria described above. The exception was Site 13, which was located on the grounds of a hospital instead of being a rear yard of a residential property.

The distribution of the target properties covered the residential quadrant in a relatively uniform manner. Figure 1 shows the location of the 13 UCAR-area sites in relation to the UCAR buildings. Table 1 lists the geographic coordinates of the sampling sites according to the 6° Universal Transverse Mercator (UTM) projection.

Figure 1: Location of Sampling Sites - UCAR Carbon Canada Incorporated Survey

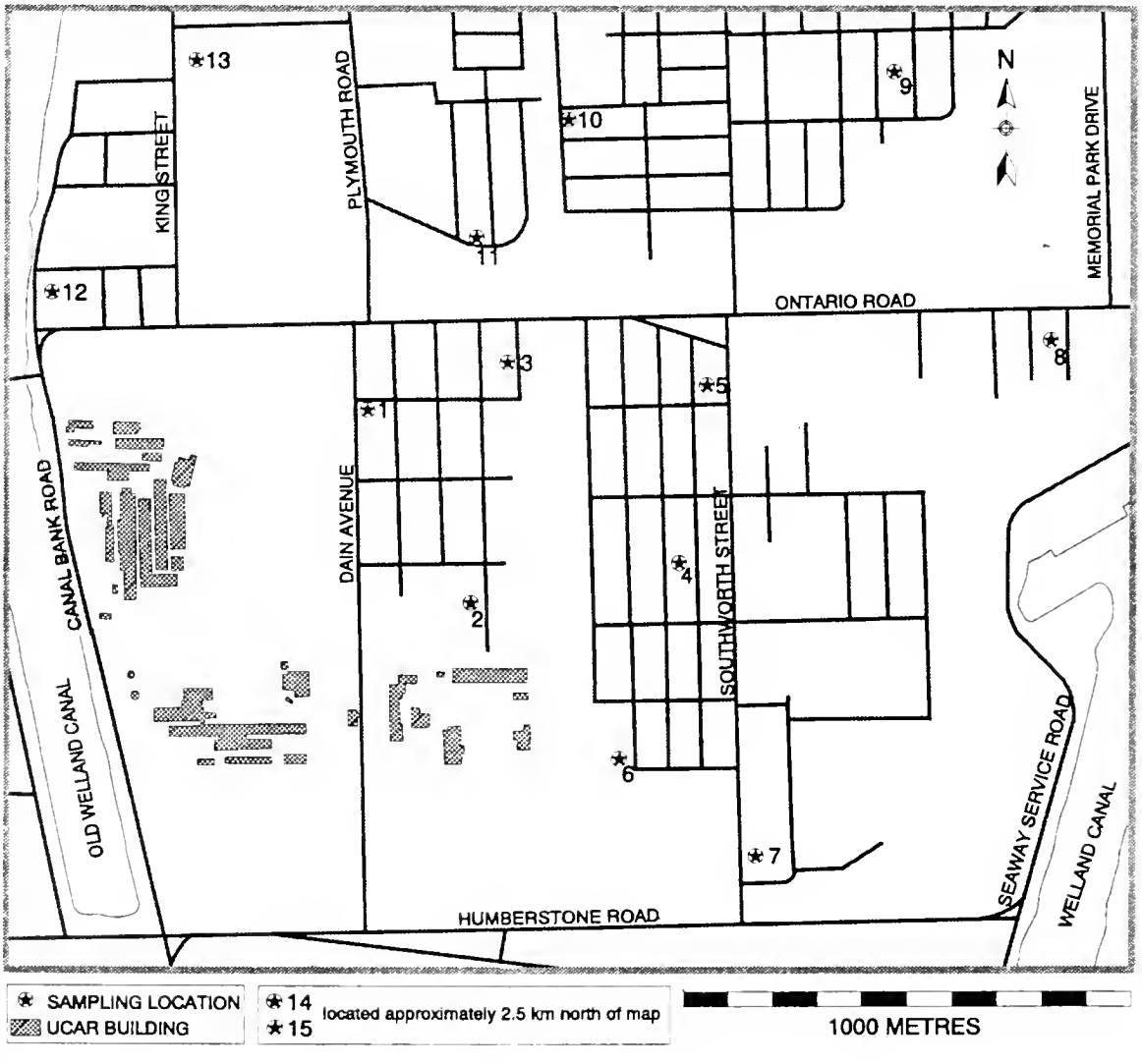


Table 1: Sampling Site UTM Coordinates			
Site	Zone	Easting	Northing
1	17	0643010	4759040
2	17	0643240	4758640
3	17	0643320	4759180
4	17	0643710	4758720
5	17	0643780	4759120
6	17	0643570	4758270
7	17	0643880	4758020
8	17	0644540	4759210
9	17	0644190	4759830
10	17	0643460	4759710
11	17	0643260	4759460
12	17	0642300	4759330
13	17	0642630	4759850
14	17	0642400	4762300
15	17	0642300	4762200

3 Sampling and Analytical Procedures

Prior to sampling, all equipment which would contact a sample was washed with a laboratory detergent solution, rinsed with distilled water, and then sequentially rinsed with acetone and hexane. Amber glass jars, which would contain the samples, had aluminum foil lining on the lid and had been solvent-washed by the analytical laboratory.

A soil sample consisted of approximately 10 cores, two centimetres in diameter and five centimetres deep. The cores were obtained with an Oakfield™ chromed steel, soil corer from throughout the lawn area, avoiding apparently disturbed areas. The cores were placed into a stainless steel bowl and homogenized with a stainless steel spoon. The soil was then transferred to the glass sample jar.

Tree foliage samples were obtained by cutting a branch from the side of the silver maple tree facing UCAR and removing approximately 20 leaves. These leaves were cut into fragments, approximately five square centimetres in size, using stainless steel scissors, mixed in a stainless steel bowl and transferred to the 250 ml glass jar.

All samples were labelled and a sketch of the property prepared showing the location of the sample tree and the soil sampling area. This would facilitate re-sampling in the future.

Soil and foliage samples were delivered to the MOEE Laboratory Services Branch (LSB) with a request to determine the concentrations of a variety of PAH compounds. Details of the methods can be obtained from the laboratory by citing method PSAPAH-E3350A for soil samples and PVAPAH-E3352A for vegetation samples. These methods provide PAH concentrations in soil on a dry weight basis; and in vegetation on a fresh weight basis.

The LSB routinely analyses soil and vegetation samples for 16 PAH compounds. The rationale for selecting these 16 compounds is related to the adoption of the US-EPA analytical methods by LSB.

The Appendix contains information about these 16 compounds in the form of structural and molecular formulas, molecular weights and boiling points. The order of presentation is based on the molecular weight and structural complexity. High molecular weight PAHs have high boiling points and are more likely to persist in soil and vegetation. Eight of these compounds, those on the right side of the appendix page, are considered possible or probable human carcinogens (Menzie et al, 1992)[1].

In 1992, the sampling was conducted on September 15. A workload backlog at the laboratory prevented analysis and the samples were held in a refrigerator (i.e. unfrozen) for about ten months. There was concern that PAH compounds present in the 1992 samples may have degraded in storage. Consequently, the survey was repeated on July 23, 1993. Analyses of **all** samples were completed by October, 1993.

4 Results

The concentrations of individual PAH compounds in each soil and foliage sample are listed in Tables 2 through 5. Eighty-eight percent of the foliar concentrations of PAHs were below the analytical detection limits, indicated by the code '<W'. Virtually all remaining foliar concentrations were qualified with the code '<T', indicating a measurable trace quantity. Only one datum was not qualified. Soil concentrations were generally of sufficient magnitude to be reported without qualifiers.

Prior to attempting an interpretation of these data, some simplification of the information was required. The most basic simplification would have been to total the concentrations of the 16 PAHs in each sample. However, because many of the data were qualified, the concept of 'Net Total' was developed. A 'Net Total' concentration was calculated by summing the individual PAH concentrations as reported and then subtracting the sum of the individual detection limits (<W values). A 'Net Total' concentration can be described as the total of individual PAH concentrations above the detection limits.

This approach treated each sample equally and provided a single datum representing a PAH concentration above a certain base level. This base level was 380 nanograms per gram, which was the sum of the <W detection limits of the 16 PAH compounds. The 'Net Total' concentrations are presented in the respective Tables 2 through 5, and are plotted as histograms in Figures 2 and 3.

---

1 Menzie, C.A., B.B. Potocki and J. Santodonato, *Exposure to Carcinogenic PAHs in the Environment*, Envi. Sci. Technol. Vol. 26. No. 7, 1992

Table 2:	PAH Concentrations in Surface Soil (ng/g d.w.) UCAR Survey - 1992

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Naphthalene	20 <W	20 <W	20 <W	20 <W	29 <T	26 <T	29 <T	20 <W
Acenaphthylene	20 <W	45 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	21 <T	216	29 <T	21 <T	24 <T	38 <T	20 <W	20 <W
Fluorene	20 <W	106 <T	20 <W	20 <W	20 <W	22 <T	20 <W	20 <W
Phenanthrene	202	1164	186 <T	236	208	286	60 <T	39 <T
Anthracene	28 <T	230	26 <T	43 <T	30 <T	47 <T	20 <W	20 <W
Fluoranthene	415	3136	387	456	492	608	120 <T	88 <T
Pyrene	358	2489	326	377	410	540	105 <T	80 <T
Benzo(a)anthracene	249	1334	224	302	325	421	82 <T	65 <T
Chrysene	278	1262	234	311	393	427	76 <T	59 <T
Benzo(k)fluoranthene	270	1225	241	336	319	421	84 <T	20 <W
Benzo(b)fluoranthene	324	1207	286	394	413	530	84 <T	61 <T
Benzo(a)pyrene	331	1417	295	445	396	592	103 <T	83 <T
Indeno(1,2,3-cd)pyrene	427	1623	293 <T	506	420	640	45 <T	46 <T
Benzo(g,h,i)perylene	351 <T	1319	263 <T	418	342 <T	544	40 <W	40 <W
Dibenz(a,h)anthracene	136 <T	561	112 <T	163 <T	40 <W	253 <T	40 <W	40 <W
'NET TOTAL' PAH	**3070**	**16974**	**2582**	**3688**	**3501**	**5035**	**568**	**341**

	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15
Naphthalene	34 <T	30 <T	23 <T	40 <T	59 <T	28 <T	33 <T
Acenaphthylene	20 <W	20 <W	20 <W	20 <W	87 <T	20 <W	20 <W
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Phenanthrene	25 <T	210	141 <T	176 <T	260	22 <T	39 <T
Anthracene	20 <W	37 <T	20 <W	21 <T	49 <T	20 <W	20 <W
Fluoranthene	47 <T	454	224	363	999	44 <T	70 <T
Pyrene	47 <T	345	180 <T	304	987	42 <T	65 <T
Benzo(a)anthracene	44 <T	186 <T	112 <T	185 <T	601	44 <T	55 <T
Chrysene	41 <T	163 <T	121 <T	200 <T	499	39 <T	51 <T
Benzo(k)fluoranthene	46 <T	173 <T	115 <T	180 <T	622	47 <T	60 <T
Benzo(b)fluoranthene	47 <T	185 <T	140 <T	205	695	40 <T	50 <T
Benzo(a)pyrene	69 <T	207	133 <T	204	719	62 <T	70 <T
Indeno(1,2,3-cd)pyrene	40 <W	249 <T	112 <T	215 <T	767	40 <W	40 <W
Benzo(g,h,i)perylene	40 <W	210 <T	134 <T	196 <T	626	40 <W	40 <W
Dibenz(a,h)anthracene	40 <W	40 <W	40 <W	40 <W	208 <T	40 <W	40 <W
'NET TOTAL' PAH	**220**	**2169**	**1175**	**2009**	**6838**	**188**	**313**

Table 3:	PAH Concentrations in Surface Soil (ng/g d.w.) UCAR Survey - 1993

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Naphthalene	20 <W	44 <T	20 <W	20 <W	20 <W	20 <W	32 <T	27 <T
Acenaphthylene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	150 <T	20 <W	20 <W	26 <T	20 <W	20 <W	20 <W
Fluorene	20 <W	64 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Phenanthrene	115 <T	820	252	90 <T	182 <T	83 <T	58 <T	37 <T
Anthracene	20 <W	206	222	20 <W	28 <T	20 <W	20 <W	20 <W
Fluoranthene	311	2920	607	417	429	160 <T	120 <T	80 <T
Pyrene	311	2413	506	370	354	141 <T	106 <T	73 <T
Benzo(a)anthracene	240	1906	394	366	275	135 <T	105 <T	72 <T
Chrysene	259	1796	398	369	288	141 <T	96 <T	67 <T
Benzo(k)fluoranthene	324	2424	460	437	325	163 <T	111 <T	81 <T
Benzo(b)fluoranthene	375	2414	593	549	470	191 <T	144 <T	87 <T
Benzo(a)pyrene	409	2950	646	631	479	193 <T	169 <T	112 <T
Indeno(1,2,3-cd)pyrene	490	3161	834	833	661	202	177 <T	105 <T
Benzo(g,h,i)perylene	400 <T	2593	649	666	498	156 <T	170 <T	126 <T
Dibenz(a,h)anthracene	141 <T	540	253 <T	275 <T	193 <T	51 <T	40 <W	40 <W
'NET TOTAL' PAH	**3095**	**24041**	**5514**	**4723**	**3888**	**1336**	**1028**	**607**

	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15
Naphthalene	20 <W	20 <W	20 <W	139 <T	35 <T	20 <W	20 <W
Acenaphthylene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Phenanthrene	28 <T	73 <T	99 <T	253	173 <T	20 <W	32 <T
Anthracene	20 <W	20 <W	20 <W	34 <T	24 <T	21 <T	20 <W
Fluoranthene	56 <T	191 <T	235	477	316	20 <W	64 <T
Pyrene	56 <T	165 <T	201	385	261	26 <T	59 <T
Benzo(a)anthracene	61 <T	131 <T	164 <T	275	194 <T	37 <T	58 <T
Chrysene	60 <T	127 <T	169 <T	273	191 <T	32 <T	57 <T
Benzo(k)fluoranthene	66 <T	163 <T	183 <T	289	205	39 <T	66 <T
Benzo(b)fluoranthene	75 <T	177 <T	220	364	255	37 <T	72 <T
Benzo(a)pyrene	95 <T	215	234	364	271	60 <T	89 <T
Indeno(1,2,3-cd)pyrene	40 <W	227 <T	259 <T	409	309 <T	40 <W	70 <T
Benzo(g,h,i)perylene	106 <T	216 <T	223 <T	322 <T	265 <T	74 <T	102 <T
Dibenz(a,h)anthracene	40 <W	98 <T	112 <T	143 <T	119 <T	40 <W	40 <W
'NET TOTAL' PAH	**403**	**1503**	**1819**	**3407**	**2298**	**146**	**429**

Table 4:	PAH Concentrations in Silver Maple Foliage (ng/g f.w.) UCAR Survey - 1992

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Naphthalene	20 <W	20 <W	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthylene	20 <W	20 <W	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	20 <W	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Phenanthrene	20 <W	20 <W	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Anthracene	20 <W	20 <W	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Fluoranthene	29 <T	58 <T	NA	20 <W	20 <W	27 <T	20 <W	27 <T
Pyrene	32 <T	75 <T	NA	20 <W	26 <T	33 <T	23 <T	23 <T
Benzo(a)anthracene	40 <T	77 <T	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Chrysene	53 <T	198 <T	NA	41 <T	45 <T	54 <T	37 <T	42 <T
Benzo(k)fluoranthene	20 <W	86 <T	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(b)fluoranthene	20 <W	123 <T	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(a)pyrene	20 <W	100 <T	NA	20 <W	20 <W	20 <W	20 <W	20 <W
Indeno(1,2,3-cd)pyrene	40 <W	40 <W	NA	40 <W	40 <W	40 <W	40 <W	40 <W
Benzo(g,h,i)perylene	40 <W	40 <W	NA	40 <W	40 <W	40 <W	40 <W	40 <W
Dibenz(a,h)anthracene	40 <W	40 <W	NA	40 <W	40 <W	40 <W	40 <W	40 <W
'NET TOTAL' PAH	**74**	**577**	**NA**	**21**	**31**	**54**	**20**	**32**

	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15
Naphthalene	20 <W	20 <W	36 <T	20 <W	20 <W	20 <W	20 <W
Acenaphthylene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	76 <T	20 <W
Phenanthrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Anthracene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluoranthene	20 <W	22 <T	33 <T	26 <T	20 <W	20 <W	20 <W
Pyrene	20 <W	25 <T	52 <T	28 <T	21 <T	20 <W	20 <W
Benzo(a)anthracene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Chrysene	42 <W	64 <T	126 <T	53 <T	41 <T	20 <W	20 <W
Benzo(k)fluoranthene	20 <W	20 <W	47 <T	20 <W	20 <W	20 <W	20 <W
Benzo(b)fluoranthene	20 <W	20 <W	61 <T	20 <W	20 <W	20 <W	20 <W
Benzo(a)pyrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Indeno(1,2,3-cd)pyrene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Benzo(g,h,i)perylene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Dibenz(a,h)anthracene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
'NET TOTAL' PAH	**22**	**51**	**235**	**47**	**22**	**56**	**0**

Table 5:	PAH Concentrations in Silver Maple Foliage (ng/g f.w.) UCAR Survey - 1993

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Naphthalene	57 <T	47 <T	64 <T	20 <W	20 <W	37 <T	22 <T	20 <W
Acenaphthylene	27 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	24 <T	20 <W
Phenanthrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Anthracene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	22 <T
Pyrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(a)anthracene	20 <W	85 <T	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Chrysene	20 <W	206	20 <W	20 <W	42 <T	20 <W	20 <W	20 <W
Benzo(k)fluoranthene	20 <W	85 <T	20 <W	20 <W	20 <W	48 <T	20 <W	20 <W
Benzo(b)fluoranthene	20 <W	98 <T	20 <W	20 <W	20 <W	56 <T	20 <W	20 <W
Benzo(a)pyrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Indeno(1,2,3-cd)pyrene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Benzo(g,h,i)perylene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Dibenz(a,h)anthracene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
'NET TOTAL' PAH	**44**	**421**	**44**	**0**	**22**	**81**	**6**	**2**

	Site 9	Site 10	Site 11	Site 12	Site 13	Site 14	Site 15
Naphthalene	21 <T	20 <W	20 <W	23 <T	20 <W	20 <W	20 <W
Acenaphthylene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Acenaphthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluorene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Phenanthrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Anthracene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Fluoranthene	20 <W	24 <T	20 <W	20 <W	20 <W	20 <W	20 <W
Pyrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(a)anthracene	20 <W	74 <T	20 <W	20 <W	20 <W	20 <W	20 <W
Chrysene	20 <W	57 <T	67 <T	20 <W	20 <W	20 <W	20 <W
Benzo(k)fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(b)fluoranthene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Benzo(a)pyrene	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W	20 <W
Indeno(1,2,3-cd)pyrene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Benzo(g,h,i)perylene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
Dibenz(a,h)anthracene	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W	40 <W
'NET TOTAL' PAH	**1**	**95**	**47**	**3**	**0**	**0**	**0**

Figure 2:

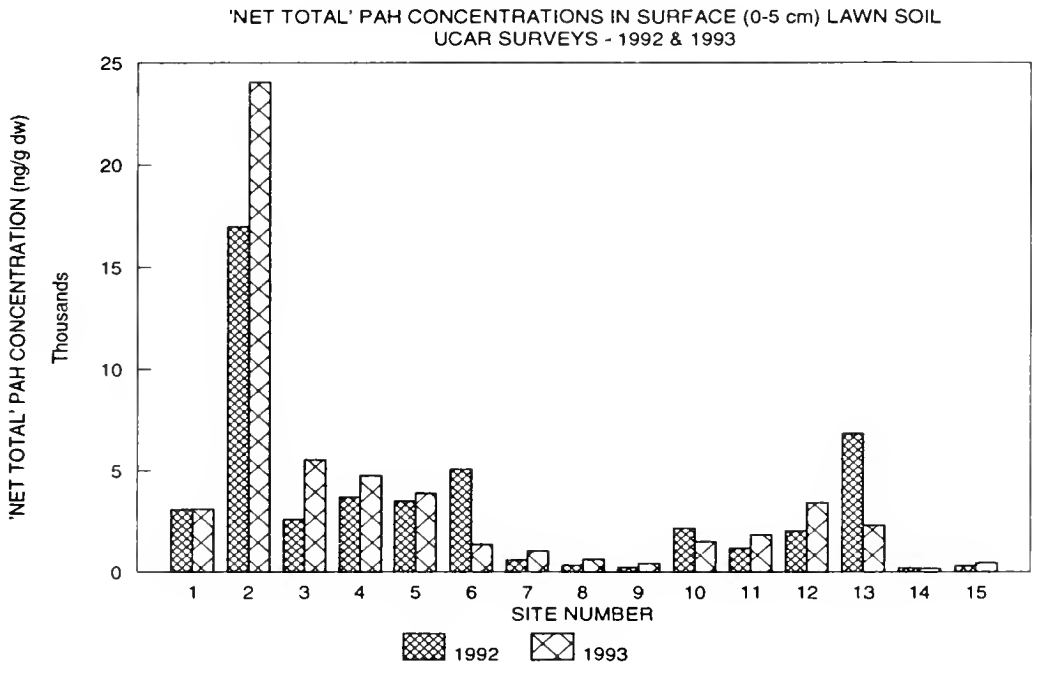
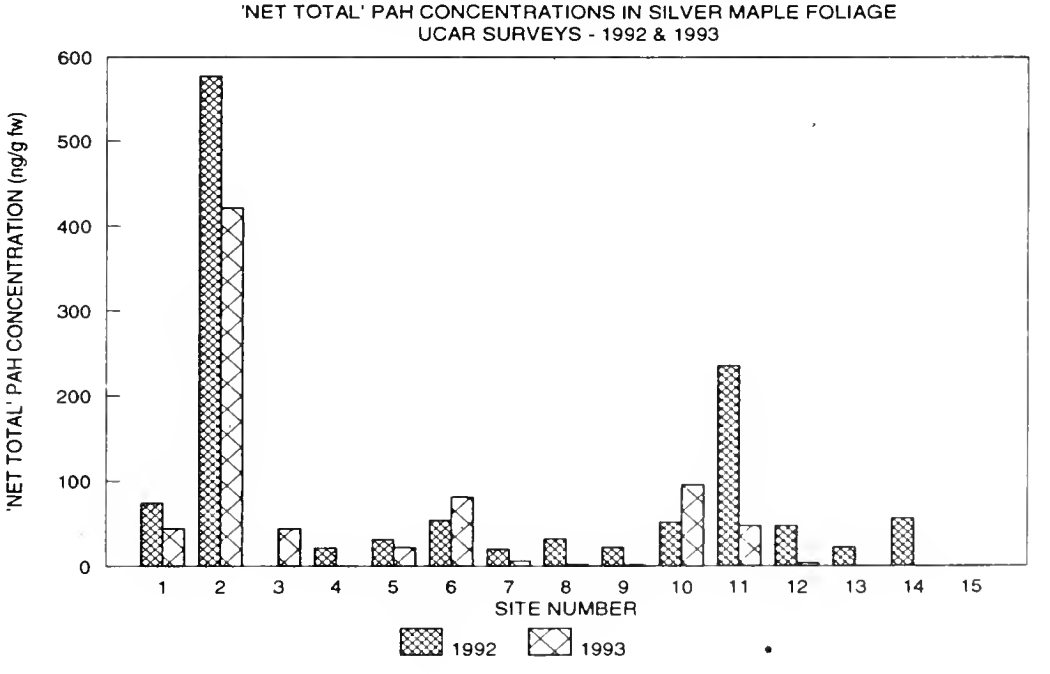


Figure 3:



5 Discussion

Polynuclear aromatic hydrocarbons are widely distributed in the environment. Natural sources include forest and prairie fires and volcanic eruptions. Any process that involves high temperature pyrolysis of naturally occurring organic material, such as coal, is a potential source of PAHs. Coke production is one such source. PAHs are also present in a variety of products derived from petroleum hydrocarbons, such as asphalt. Consequently, it is quite common to encounter PAHs in the environment where there are no near-by point sources.

5.1 PAHs in Soil

The sampling sites in this survey contain a wide range of soil PAH concentrations. However, these sites can be assigned to three groups according to the relative magnitudes of the 'Net Total' concentrations.

Figure 2 reveals that soil from Site 2 contains about 20,000 nanograms per gram (ng/g) of these PAHs. This is by far the highest concentration encountered. A group of nine sites (1,3,4,5,6,10,11,12,13) have concentrations in the 1,000 to 5,000 ng/g range. The third group contains five sites (7,8,9,14,15) with soil concentrations below 1,000 ng/g.

The sites within each group are located at different relative distances from the UCAR property. Site 2 is located within 200 metres of some of the UCAR process buildings. The second group includes sites within the residential neighbourhoods to the north and east of UCAR. The third group consists of sites that are furthest from UCAR, and includes the two control sites. This pattern implicates UCAR as the source of the PAHs in the soil.

The data also suggest that the UCAR influence is limited to the immediate vicinity of the plant. PAHs in soil at Sites 8 and 9, the most distant of the UCAR-area sites at about 1.5 kilometres from the nearest UCAR building, are very similar to the control Sites 14 and 15.

With this limited data set, it is not possible to delineate the contamination zone with certainty. The concentrations encountered in the soil at a given site would be influenced by the intensity of the deposition and the length of time that the soil was exposed to such deposition. A property that had new soil added or indigenous soil tilled would likely have lower concentrations than a neighbouring property which was not amended.

The data also contain some discrepancies. Samples collected from the same site in the two successive years usually have similar concentrations. This suggests that the effect of the 1992 sample analysis delay was minimal. However, on occasion the concentrations of PAHs in the paired samples differed. The 1992 Sites 6 and 13 "Net Total" soil concentrations were about

threefold higher than the respective 1993 concentrations. The Site 6 discrepancy can be ascribed to sampling in different parts of the yard. The location of the 1992 sample was found to be disturbed during the 1993 visit and a sample had to be collected from a different part of the yard.

The 1992 Site 13 sample had relatively high concentrations of PAHs when compared to sites closer to, or at similar distances from, UCAR. There may be a local source responsible for a heterogeneous distribution of PAHs in soil at this site. One possibility is runoff from an asphalt-paved parking lot which is very close to and uphill from the sampling site.

Frequently when there are complicating factors such as alternate sources of an identical contaminant, or variable receptor exposure period, it becomes very difficult to ascribe a contaminant to a source. However, if the source is sufficiently large, these complications are relegated to the status of minor anomalies. This is the case for PAH emissions by UCAR. The emissions and deposition of PAHs are of significant magnitude and duration that they have contaminated the soil on various residential properties in the vicinity of the source.

5.2 PAHs in Foliage

The PAH in silver maple foliage data are dominated by one observation; namely that the foliage at Site 2 contains a quantity of PAH compounds substantially higher than at other sites. The "Net Total" concentrations of PAHs were 577 and 421 ng/g, on a fresh weight basis, in 1992 and 1993, respectively. Virtually all other samples had concentrations below 100 ng/g, with the exception of the 1992 sample from Site 11. Since the 1993 sample from the same tree had a much lower concentration, the 1992 datum is considered an anomaly.

The quantification of PAHs in tree foliage is not a routine procedure for the Phytotoxicology Section. The experience is limited to collection of foliage samples near three tire fires in 1990. PAHs were not detected in such samples at two small fires, near Kingsville and Gormley. They were detected on spruce needles collected near the Hagersville tire fire. Unfortunately, a concentration comparison is not possible because the Hagersville samples were processed in a different manner. The needles were washed with a solvent and the solvent analyzed.

The presence of PAHs in the silver maple foliage samples from Site 2 indicates an active deposition process. Assuming that the uptake of PAHs from soil is minimal, these compounds could only have accumulated between the time the foliage emerged in the spring and the time of sampling. This is contrary to the situation in soil where PAHs would accumulate as long as microbial degradation or photo-oxidation of the PAH compounds was slower than the rate of deposition. Therefore, foliar PAH concentrations should reflect concentrations in the ambient air during the current growing season, whereas soil PAH concentrations should reflect longer-term deposition.

5.3 UCAR-Area Soil PAHs in Perspective

To this point, this report has identified PAH soil contamination, ascribed it to the UCAR operation, and delineated, in broad terms, its intensity and geographic extent. It remains to place this contamination into perspective by comparing the UCAR concentrations to those encountered elsewhere. Table 6 compares the 1993 concentrations detected at UCAR Sites 2 and 3 to concentrations encountered during two 1990 background soil surveys, one in Toronto and the other in Windsor.

The Toronto survey was conducted by SENES Consultants Ltd.[2] and involved sampling 30 municipal parks in the urban core of the City of Toronto. The Windsor survey was conducted by the MOEE Phytotoxicology Section[3] and sampled 12 parks throughout the City of Windsor. In both cases the soil samples were collected from the top five centimetres in the same manner as in the UCAR survey. The Toronto and Windsor concentrations represent individual park sites with the highest frequencies of maximum concentrations, and therefore represent 'worst-case' soil contamination by PAHs from a variety of background sources in an urban environment.

Table 6:	Soil PAH Concentrations (ng/g d.w.) UCAR Sites 2 and 3 vs. Toronto and Windsor Parks			
	Welland UCAR Site 2 (1993)	Welland UCAR Site 3 (1993)	Toronto park (1990)	Windsor park (1990)
Naphthalene	44 <T	20 <W	50 <	20 <W
Acenaphthylene	20 <W	20 <W	50 <	20 <W
Acenaphthene	150 <T	20 <W	80	20 <W
Fluorene	64 <T	20 <W	130	20 <W
Phenanthrene	820	252	730	236
Anthracene	206	222	200	58 <T
Fluoranthene	2920	607	900	754
Pyrene	2413	506	930	583
Benzo(a)anthracene	1906	394	na	369
Chrysene	1796	398	680	253
Benzo(k)fluoranthene	2424	460	na	417
Benzo(b)fluoranthene	2414	593	na	577
Benzo(a)pyrene	2950	646	590	453
Indeno(1,2,3-cd)pyrene	3161	834	490	789
Benzo(g,h,i)perylene	2593	649	560	506
Dibenz(a,h)anthracene	540	253 <T	na	108 <T

2 SENES Consultants Ltd. *Soil Sampling Program for Determination of Background Levels of PAH'S in Toronto Soils*, Report to the Corporation of the City of Toronto Housing Department, February, 1991

3 Gizyn, W.I., *Windsor Air Quality Study - Soil and Garden Produce Survey Results*, Ministry of Environment and Energy, 1994

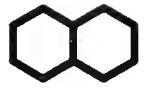
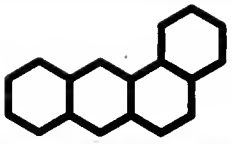
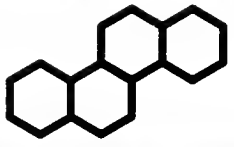
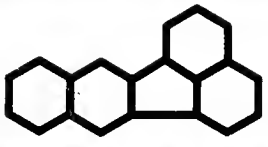
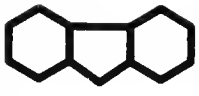
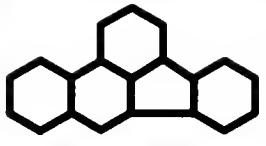
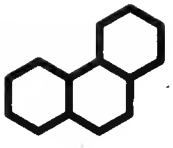
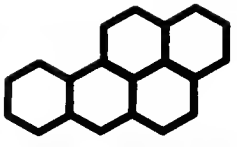
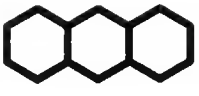
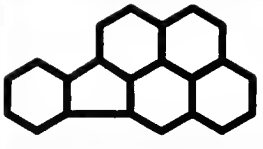
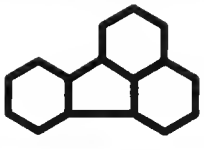
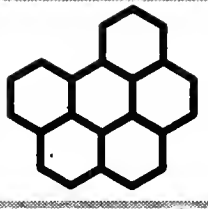
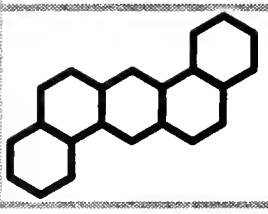
This comparison reveals that the soil PAH concentrations encountered at UCAR Site 2 clearly exceed the concentrations encountered in the most heavily contaminated Toronto and Windsor park soil. The concentrations at UCAR Site 3 are very similar to the 'worst-case' sites in Toronto and Windsor. This is a clear indication that the soil PAH concentrations near UCAR in Welland are source-oriented and they are higher than normally encountered in an urban environment.

6 Conclusions

Emissions of PAH compounds by the UCAR Carbon Canada Incorporated plant in Welland have resulted in the contamination of soil on neighbouring residential properties. The soil PAH concentrations at survey sites close to UCAR were similar or higher than the highest concentrations encountered in urban parks during background surveys. The geographic extent of the UCAR influence on soil appears to be limited to within approximately one kilometre of the plant. The contamination of tree foliage by PAH compounds indicates current deposition.

7 Appendix

Molecular Structures, Formulae and Weights and Boiling Points of 16 Polynuclear Aromatic Hydrocarbons

 Naphthalene $C_{10}H_8$ MW = 128.18 BP = 218	 Benzo(a)anthracene $C_{18}H_{12}$ MW = 228.30 BP = 435
 Acenaphthylene $C_{12}H_8$ MW = 152.20 BP = 270	 Chrysene $C_{18}H_{12}$ MW = 228.30 BP = 448
 Acenaphthene $C_{12}H_{10}$ MW = 154.20 BP = 278	 Benzo(k)fluoranthene $C_{20}H_{12}$ MW = 252.32 BP = 481
 Fluorene $C_{13}H_{10}$ MW = 166.23 BP = 295	 Benzo(b)fluoranthene $C_{20}H_{12}$ MW = 252.32 BP = 481
 Phenanthrene $C_{14}H_{10}$ MW = 178.24 BP = 339	 Benzo(a)pyrene $C_{20}H_{12}$ MW = 252.32 BP = 495
 Anthracene $C_{14}H_{10}$ MW = 178.24 BP = 340	 Indeno(1,2,3-cd)pyrene $C_{22}H_{12}$ MW = 276.34 BP = 536
 Fluoranthene $C_{16}H_{10}$ MW = 202.26 BP = 375	 Benzo(g,h,i)perylene $C_{22}H_{12}$ MW = 276.34 BP = 525
 Pyrene $C_{16}H_{10}$ MW = 202.26 BP = 393	 Dibenz(a,h)anthracene $C_{22}H_{14}$ MW = 278.36 BP = 524